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Fundamentals Of Aerial Recovery

6593rd TEST SQUADRON (SPECIAL)

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AUGUST 1968

6593D TEST SQUADRON (SPECIAL)

PILOT TRAINING GUIDE

"FUNDAMENTALS OF AERIAL RECOVERY"

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I. INTRODUCTION

A. The purpose of this text is to provide a basic generalized explanation of the equipment and pilot techniques used in aerial recovery. Its emphasis is on the training situation, and it is intended to be informative to the pilot, rather than directive. As in all flying, detailed techniques vary somewhat from pilot to pilot, and basic directives and regulations change from time to time. Details of the aircraft systems are available in appropriate handbooks or manuals, and operational procedures are established in other documents. The information in this document is current and reasonably complete at the time of writing, but may not remain so. Therefore, it is hoped the reader will accept the information and recommendations in this text as a training aid to provide a basis for questions, discussion and further study.

B. Explanation of Terms: The following list of terms, although not necessarily peculiar to aerial recovery, are used in the text. For the most part, the list includes only those terms that have an unusual sense or meaning in association with aerial recovery or parachutes.

1. Apex - the top most point of an inflated parachute.
2. Attaching straps - straps connecting a parachute clevis to a suspended weight.
3. Breathing - a periodic inflation and deflation of a parachute.
4. Clevis - a metal unit connecting either a recovery loop to a winch line or parachute suspension lines to attaching straps.
5. Coning - the horizontal circular motion of a parachute around a given point, normally associated with a tandem parachute system.
6. Contact - a touching of the extended recovery gear with a system.
7. De-rig - any action which results in separating any part of the recovery loop from the poles.
8. Fishline - the in-trail position of a recovery loop not attached to the poles but suspended on the winch line behind and below the aircraft.
9. Heavy suspension line - a reinforced vertical parachute line

10. High Speed Run - a maneuver designed to put the aircraft within visual acquisition range of a system in minimum time which includes the factors of range and altitude.

Lateral - a horisontal reinforced parachute band.

Look-See - a visual inspection of a system in flight.

13. Mae West - deformation of a parachute caused by a suspension line looped over the top of a parachute.

14. Reefed - the intentional or unintentional gathering of parachute suspension lines which results in only partial inflation.

15. Rigged - aerial recovery equipment is extended from the aircraft and ready for recovery.

16. Sheave - the gathering together of parachute suspension lines which occurs when a parachute collapses after recovery.

Skirt - the bottom edge of an inflated parachute.

Splash - physical contact of any article with the ocean surface.

Streamer - a parachute that does not open.

Suspension line - a vertical parachute line.

21. System - a parachute or combination of parachutes and the associated suspended weight.

22. Tear Through - physical contact of a parachute which does not result in recovery.

23. Weather box - a maneuver designed to maintain close-in electronic surveillance of a system in flight.

Visual - visual acquisition of a system in flight.

II RECOVERY PARACHUTE SYSTEMS

1. The parachute system may be a single parachute or a combination of parachutes or devices. It is the recovery target and after contact it is the link between the aircraft gear and the recoverable package. Its design affects recovery reliability, and also affects the forces imposed by the aircraft, its recovery gear, and the recoverable package during recovery.

2. Minimum packed bulk, minimum weight, reliable deployment, in-flight stability and sufficient size to provide a reasonable rate of descent for a given suspended weight are important normal parachute design criteria. The requirements and stresses of aerial recovery impose additional problems to the parachute designer. Development of parachute systems suitable for aerial recovery has taken several directions to meet the recovery requirements with various suspended weights and allowable package "G" loads.

A. The Mark 5C Parachute: Early parachute systems used for leightweight recoveries were modifications of standard cargo or personnel parachutes, specially reinforced to withstand aerial recovery. Even after a great deal of experimentation with parachute size, shape, porousity, venting techniques and skirt design, the early systems all left something to be desired in stability and reliability. Parachute oscillation, "breathing," and other erratic flight behavior made working these systems more than a challenge to the recovery pilot. Under ideal conditions recovery was difficult; under adverse conditions, almost impossible. Recovery reliability was relatively low with such parachute systems.

(1) Finally, a type of "ring-slot" parachute was developed and adapted for recovery. Using broad ribbons of fabric separated by radial gaps, or slots, the ring slot parachute deployed reliably, had acceptably low packed weight and bulk, and proved exceptionally stable in flight. The first ring-slot recovery design had three reinforced lateral bands (numbered 1 through 3, top to bottom) and twelve reinforced suspension lines. It was designated the Mark 5B-3, the Mark 5 for the shape of the inflated canopy, the B for "ring-slot" (The MK 5A had a solid canopy), and the 3 for the number of laterals. Subsequent testing resulted in the addition of another lateral, designed #4, placed between the #1 lateral and the canopy apex, to increase recoverability. The parachute became the Mark 5B-4. A later modification of the suspension lines to reduce weight has been designated the Mark 5C, but for the canopy construction and basic reinforced description, that follows, the Mark 5B-4 and Mark 5C are identical. The Mark 5C is now the standard training parachute and is manufactured by several companies.

(2) The Mark 5C is a nylon twenty-four gore ring-slot parachute with a nominal diameter of 29.7 feet and a weight of approximately 20

pounds. Its inflated width across the skirt is slightly less than 20 feet, and the distance from the skirt to the load clevis is a little over 24 feet. Every second suspension line (12 of 24 total) is of 1500 pound (static) tensile strength, while the remaining lines are of 300 pounds strength. Each of the four reinforced laterals is of 2400 pound strength. All reinforced lines are polyvinyl chloride (PVC) impregnated to reduce nylon burning, caused by friction during recovery.

(3) The breaking force for nylon cord under rapid loading may drop to as low as 60% of its static breaking force, depending upon the rapidity of load change. The Mark 5 was designed with a 50% safety margin (1.5 maximum expected load) using static strength values for the cord. Thus, it is apparent that the strength of the parachute can be critical under the impact and dynamic loading forces experienced during recovery.

(4) On contacts where only one reinforced line is engaged, design limits will usually be exceeded, and a tear-through is probable. Although the Mark 5 is a proven parachute, its reliability is dependent upon good recovery contacts at altitudes and airspeeds within established limits. The slower the true airspeed of the aircraft, the lower is the possibility of tear-through in the event of a poor contact.

B. Other Parachute Systems:

(1) A family of recovery parachute, ranging gradually from small to large, does not exist as such. Special parachute systems for varied special uses and weights do exist, however. Such systems are of three types: Mark 5 modifications, conical extension parachutes, and tandem systems.

(2) Mark 5 modifications are scaled versions of the standard parachute. Aircraft recovery rig geometry, of course, places a parctical limit on the maximum size of canopy that can be contacted directly without imposing excessive impact loads on the recovery poles, mounts, ramp and aircraft. A nominal diameter of 40 feet or so would appear to be about the limiting size.

(3) The second type, the conical extension parachute, has a reinforced truncated cone on the top of the canopy. The cone, rather than the canopy, is the target for the contact. Although there is no recovery restriction to canopy size for this type of parachute, some deployment and structual problems have been encountered. This has, until the writing, limited its use to medium weight applications. (235 to 800 lbs).

(4) The third type, the tandem system, uses two parachutes stacked vertically and connected by a load line. Only the top parachute must be sized and stressed for recovery impact. The size of the bottom parachute is limited only by material and parachute technology.

(Ultimately, the weight that the aircraft can carry in trail). A tandem system has the advantage that, in the event of tear-through of the top (recovery) parachute, the package is still supported by the bottom parachute, avoiding catastrophic descent. Also because of the "sheave" effect of the long load line after contact, "G" forces at the package are lower than on single systems. The disadvantage of most tandem systems is the system movement - the top recovery parachute flies in the wake of the usually larger bottom parachute, and, carrying the weight of the load line, usually lays over a little to one side. This frequently results in "breathing", "coning", or other erratic top parachute movement, in the vertical as well as the horizontal plane, making achievement of a good contact often difficult, and sometime hazardous.

(5) Regardless of whether the parachute is a standard Mark 5C, a conical extension, or a tandem system, the pilot's job remains that of achieving the best possible contact. Special training is conducted for all non-standard systems as the requirement arises.

III AIRCRAFT PERFORMANCE:

A general discussion of aircraft performance factors as they apply to recovery is an aid to understanding the techniques of aerial recovery presented in the sections to follow. Aircraft descent and configuration airspeed limitations are important in establishing the working envelope of parachute system descent rates. Maneuverability is of primary importance when establishing a working pattern close to the system, and together with pilot ability, is essential to the achievement of good contacts. Center of gravity considerations are of lesser importance so long as normal handbook limitations are observed. The pilot should be aware, however, that center of gravity changes do occur during the recovery cycle.

1. Aircraft descent/airspeed limitations and aircraft handbook limitations will be observed in all configurations. With wing flaps 50% gear up, aft cargo door and ramp open, the limiting airspeed is 150 knots, based on C-130 handbook limits for the aft cargo door and ramp, and the wing flaps limit the angle of bank to 45° maximum. If the flaps are set over 50%, the maximum allowable indicated airspeed is further reduced to 145 knots.

a. At normal aircraft weights, only about a 2500 feet/minute rate of descent can be maintained. This figure has been established as the maximum system descent rate at which a parachute will normally be worked. No minimum, of course, is necessary. In an emergency, the aircraft descent rate can be increased slightly, by lowering the landing gear. The air deflectors have little drag effect, but also may be opened. Gear down recoveries are not permissible, so the landing gear must be retracted prior to making a recovery pass.

b. Normal parachute system descent rates lie between 1500 to 2000 feet per minute, well within C-130 aircraft capability, provided the system is allowed to drop to no more than a few hundred feet below the aircraft. With the recovery rig deployed, in the pickup position aircraft limitation airspeed can be flown. Keeping the airspeed between 120 and 135 knots should not be a problem to the pilot on a normal system.

c. Parachute performance is the final factor to be considered when discussing the descent capability of the aircraft. The parachute descent rate is dependent upon air density in the same manner as the aircraft TAS-IAS relationship. A parachute, at a given weight, descends at a constant vertical "IAS". Its vertical "TAS" (or actual descent rate, disregaring possible vertical wind effects) decreases with altitude, so that an abnormal system that is descending beyond the aircraft's capability at 15,000 feet may be workable at some lesser altitude.

2. Maneuverability. A discussion of aircraft maneuverability probably should be presented mathematically, for pilots have varied opinions, and presentation of calculated proof is best evidence. This

text will rely, however, on discussion of two aspects; that of control effectiveness, and that of maneuver or turn, radius. Math will be avoided, but the reader is encouraged to study the flight path figures of Section IX, depicting recovery patterns, and showing the effect of changes in angle of bank, and of altitude/TAS, upon the size and shape of recovery patterns. Special attention should be devoted to the time elapsed. A parachute descending at a given rate, together with clouds or weather, may severely time-limit a recovery operation.

a. The first aspect, control effectiveness, is complex. At low airspeeds, controls may feel "mushy" to the pilot. At higher airspeeds wheel forces increases, so that the pilot feels he has firmer control, and the aircraft may feel more responsive. In general, control effectiveness, as indicated by the direct force the control surface is able to exert, does increase with airspeed. Not so obviously, so do aircraft inertial effects, to the extent that at higher airspeeds the aircraft is actually less maneuverable, in terms of the pilot's ability to change the flight path within a given time or distance. The aircraft feels more responsive at higher airspeed, but this can be misleading to the recovery pilot. The C-130 aircraft, in particular, demonstrates more than adequate control response in the low speed regime which is the recovery envelope. So long as violent maneuvers, and airspeeds less than 120% of stall are avoided, an increase in airspeed slightly decreases rather than increases the pilot's ability to "move the aircraft" in order to "stay with" a descending parachute. Within the 10 to 15 knots airspeed spread allowable for recovery, any change in control effectiveness can be considered negligible at normal aircraft weight. This applies equally to rudder, elevator, and aileron controls. 120% of stall speed at an aircraft weight of 120,000 pounds, flaps 50%, is 120 KIAS. It follows that caution be used to avoid large control corrections if recoveries are flown at heavier aircraft weights, at this minimum recovery speed, or that an extra margin of airspeed may be desirable. In tight turns, at heavier weights, extra airspeed may be necessary to avoid stall.

b. Although the recovery pattern itself should be flown in a normal coordinated manner, uncoordinated controls may be needed, just prior to contact, because of an apparent (not actual) "control reversal" effect. This occurs because the recovery rig is below and well behind the aircraft center of gravity. In attempting to position the rig for a good parachute contact within these last few seconds, the pilot discovers that right aileron moves the rig in an arc to the left, actuation of up elevator moves the rig down, and left rudder moves the rig to the right. This occurs, of course, because the aircraft attitude begins changing almost immediately with the control actuation while the flight path momentarily is essentially unchanged, and takes several seconds to begin changing. The sense of timing and judgement needed to use this effect to best advantage comes only from experience and practice.

c. The second aspect of maneuverability is radius of turn. At a given indicated airspeed and angle of bank, the turn radius increases with altitude because of the increased true airspeed. Increasing the angle of bank, everything else held equal, decreases the radius of turn. The steeper the bank, though, the more time is spent rolling-in and rolling-out, so that the effect is not quite as direct as it might seem. Bank, of course, is ultimately limited by the handbook maximum of 60° clean, and 45° with flaps.

d. The importance of quickly achieving a low airspeed if one desires to stay in a close pattern around a given point is well demonstrated by the figures of Section IX. More important is the time that can be saved by keeping airspeed low and angle of bank high. Figure 1 shows that not only is a 45° of bank tear drop pattern smaller in size, but flying it takes about 26 seconds less than a 30° of bank pattern, and over a minute less than a 20° bank pattern. The importance of these maneuver effects will become more evident in Section IV and VI.

2. Center of gravity considerations. Movement of the dolly during rigging causes a rearward movement of the center of gravity. This is well diagrammed in the JC-130 aircraft handbooks. The CG shift is easily corrected by elevator trim, and the aircraft will remain dynamically stable through the rigging process.

a. Recovery pilots should be aware however, that, with exceptionally heavy packages in trail, the aircraft can approach neutral stability, and under unusual circumstances, with package oscillation, become momentarily unstable. The pilot must stay "on top" of his aircraft, with any heavy package in trail, and should exercise care even with lightweight systems in trail.

IV FUNDAMENTAL RECOVERY FLYING

The recovery pattern is basic to aerial recovery. Its primary purpose is to place the aircraft in position to effect aerial recovery or to make a look-see pass. Secondarily, the pattern keeps the aircraft in the vicinity of the parachute system, allowing the pilot to either make repeated passes, or to delay until ready to make the recovery pass, while maintaining visual contact with the system. Two patterns are used: The tear-drop pattern, and the circling approach. A straight-in approach may be necessary in unusual conditions, but being both self-explanatory and rarely used, will not be discussed. The weather box, used under instrument conditions, is discussed in Section VI.

1. The tear-drop pattern. The tear-drop pattern is comprised of a timed outbound leg of 20 to 30 seconds, a constant rate (bank) left turn, and an inbound leg. Its form is similar to an instrument procedure tear drop, except the legs are shorter. The included tear drop angle is usually greater than 45°, rather than 20° or 30°. The short legs are necessary to keep the aircraft close to the system. The turn should be tight rather than shallow, to save time as well as to make it easier to acquire and maintain visual contact with the system. A 25 second outbound leg, a 30° bank left turn of approximately 230° and a 25 second inbound leg, is the most commonly used pattern. This pattern is recommended for early training.

a. Prior to drop for recovery, a drop heading should be chosen which will provide the most advantageous cloud/horizon background on the intended recovery pass. If one look-see pass will be made prior to the recovery pass, the aircraft heading at drop should be such that the desired background is just aft of the left wing tip (see figure 7). If, on the other hand, there is an undersirable background area to be avoided, drop with this area between the nose and the right wing tip. An experienced pilot may sometimes recover into a [illegible] background for practice, but, early in the program, the selection of a good background is recommended.

b. With the drop heading decided, the next step is to accomplish the Pilot's Pre-Recovery/Drop Checklist down to deck troughs and shroud cutter. The proper configuration for deploying the rig, and for drop is; wing flaps as directed (usually 50%); airspeed 120 to 131 KIAS; outboard engine power near maximum continuous; and inboard power 5000 inch pounds torque or below. Airspeed control is normally maintained, prior to drop, using inbound engines only. When the checklist is nearly complete, this configuration will be established and the rig deployed for drop. While rigging, turns should be flown with minimum angle of bank.

c. The drop altitude recommended is 14,000 feet MSL. The Pilot may, however, choose to drop from a different altitude for weather, increased practice, or for other reasons. When advised by the winch operator that the rig is deployed for drop, the aft rigger will stand by to actuate the drop release on the pilot's command "Release the system - - now."

d. Prior to drop, the pilot should set his flight director heading marker about 45° to the right of the tail of the aircraft (this is approximately the inbound heading and will assist in visually locating the system in the turn). At the command "- -now" the pilot should start his clock. After drop, the rigger normally will advise "out and open". The pilot should promptly reduce power, set the outboard engines at or close to zero torque, inboards at about 1000 pounds, maintain his heading, and begin descent. Rate of descent should be 1800 to 2000 FPM, until the aft rigger advises that the system is coming up on the horizon. Then the descent rate should be adjusted, using inboard throttles, to keep the system on or perhaps slightly above (not to exceed 2 system lengths) the horizon. The descent rate should stabilize at 1600 or 1700 FPM, with the aircraft being retrimmed as necessary. The back-end crew will put the poles down and notify the pilot when he has a good rig. The Winch Operator will then reset the winch control panel. The Co-Pilot will complete the Pre-Recovery/Drop Checklist. The aircraft is now ready for recovery.

e. At 25 seconds outbound, a left turn is begun using about 30° of bank. During the first 130° or so of turn, the pilot should fly basic instruments, maintaining his airspeed, bank angle and descent rate. After about 130° of turn, the pilot should begin looking outside intermittently with his cross check, in order to acquire the system visually at the 9 o'clock position. After acquisition, he should adjust his descent rate to correct any error in his desired altitude with respect to the system.

f. As the system approaches a position in front of the aircraft, elevation should be adjusted to put the system on the horizon (or projected horizon) and rollout initiated. A good roll-out is the first important step to a good recovery and should make large corrections unnecessary later. As the aircraft approaches its proper line up position, the system's apparent movement along the horizon, from right to left, will slow down. If rollout position is overshot, the system will begin an apparent movement in the opposite direction, i.e., from left to right. The pilot should time his roll-out so that, as the wings level, the system appears stationary against the background.

g. The pilot's next duty is to inform the recovery crew of his intentions, i.e., either "dry run", "look-see", or "hot pass". If the pass is to be a look-see, the pilot lines up to pass to the right of the system and approximately level with it, for a visual inspection. For a dry run or hot pass, the pilot lines up directly on the system.

h. When lined up inbound, the pilot should insure that the airspeed is within the allowable contact envelop (120 to 131 KIAS), note whether speed is increasing or decreasing, and adjust accordingly.

Heading and elevation corrections should be made as soon as the need is sensed, because the longer delayed, the larger the required correction. Care must be exercised however. Over correction is a common problem among new recovery pilots.

i. At about 10 seconds from the system the recovery crew should be advised "10 seconds" by the co-pilot. At this time the pilot should have his attitude and airspeed established and be able to forget his instruments entirely, or else he should pull off for another pass. From this moment, he must keep a constant visual on the system and keep his eyes out of the cockpit. He allows the system to start dropping below the horizon, attempting to position the aircraft so that the apex of the parachute passes approximately 7 to 12 feet directly beneath the nose, with the parachute aligned to the line of flight. Corrections made during the last few seconds should be smooth but positive. Large corrections are not possible, even with large changes of attitude, because of the time factor. If it appears large corrections will be necessary in the last few seconds, a pull-off should be initiated, using (most importantly) power, combined with flight controls. A pull-off initiated less than three seconds out is rarely successful, so pull-off should be initiated earlier.

j. Corrections may be made using all flight controls. The elevator, with throttles, handily corrects for elevation, but both aileron and rudder affect the system lineup. One suggestion - early in the program, use coordinated aileron and rudder together for line-up correction, especially out away from the system. As you gain experience, and acquire a "feel" for the way the aircraft and rig moves with the aileron, and with the rudder, you will find yourself increasingly able to make last second "reversed control" corrections using aileron only, or rudder only, in uncoordinated fashion. Regardless of your methods, your technique should be smooth and gradual. There is no excuse for for abuse of the aircraft.

k. If the pass is a dry run or a look-see, the pilot should reset his clock for timing as he passes the system, and reset his heading marker, for the next pass. This applies also for a hot pass "miss."

l. If the pass is hot, and contact is made, the aft left rigger will call "contact" followed by the advisory "in trail" or "tear through" as appropriate. In the unlikely case that it is a tear-through without a derig, another pass may be initiated, otherwise, the pilot should go into a circling approach while the recovery crew re-rigs, before attempting another pass.

m. Assuming the riggers call is the hoped for "in trail", and the aircraft is above 10,000 feet, descent should be continued to below this altitude so that the crew may work without oxygen. When cleared by the pilot, the crew will go off oxygen, reel in, and board the system. Airspeed during reel-in and boarding should be 120 to 131 KIAS Turns, just as for rigging prior to drop, should be limited to a minimum angle of bank, outboard throttles set near max continuous, and the inboards at minimum power to maintain altitude and airspeed. After reel-in and boarding, the Pilot's Post Recovery/Drop checklist should be accomplished.

2. The Circling Approach. The circling approach is really a modified tear-drop pattern, and is usually entered by shallowing out to 10° or 15° of bank when the system reaches the wingtip (9 o'clock) on the (normally 30° bank) tear-drop turn. It also may be entered on a tangent properly distant from the system. By maintaining the 10° to 15° bank, steepening or shallowing it, to keep the system at the same distance on the wingtip, a continuous circle is flown with two characteristics. The first is that the system will remain within 2 to 3 miles, easy visual range. The second is that the pilot is in a position to turn inbound at any time, provided he maintains his descent with the system, and will be about 25 seconds out when helhelis swingingswivel inbound.

a. Because of these characteristics, the circling approach is recommended for use when the pilot is seeking a better horizon/background, when rigging or re-rigging must be accomplished, or when the pilot simply wants to wait (for any reason) for the system to reach a lower altitude, with a minimum of maneuvering. Inbound procedures are the same for the tear-drop pattern.

3. Factors Affecting the Pattern: Recovery patterns, and recoveries are flown within an indicated airspeed envelop. Because true airspeed increases with the decreased air density of higher altitude (at a given indicated airspeed) the recovery pattern is obviously larger dimensionally at higher altitude. Additionally, the higher actual speed results in higher centrifugal force while turning, so that more bank angle is required to turn at the same rate at an increased altitude. The reverse effect is obvious in a recovery pattern: At higher altitude, using the same angle of bank, the turn is larger and takes longer. This effect tends to make the pattern larger still, and the difference between the pattern at 15,000 feet and 5,000 feet, in closeness to the system, is noticeable to the pilot (see figure 8).

a. More important, perhaps, is the time taken to fly the pattern. The recommended 25 second tear-drop takes slightly less than two minutes. If weather or other circumstances limit recovery opportunity, time becomes critical. Conditions may not allow the pilot much choice as to the working altitude envelop. But the pilot can change his timing outbound, and his angle of bank.

b. If he elects to fly less than 20 seconds outbound on a tear-drop, however, he finds himself in an almost constant turn of 270° to 300° back to the system, even using a 45° bank (the limiting bank with wing flaps extended). The extra turning time surpasses that saved outbound and inbound. A twenty second pattern, with a 45° bank turn, makes about the shortest pattern, in time, that is practical. Using less than 30° of bank, or shallowing the turn, results in an excessively large pattern and lost time. (See figures 1, 2, 3 and 4).

c. Flying the recommended 25 second pattern, it can be seen that 5 passes should be avilable, before splash, using a 15,000 foot drop altitude. (See figure 8). A rule of thumb is that each pattern uses up 3,000 feet of system altitude.

4. Points for Discussion:

a. Recovery Patterns are flown using left hand turns whenever possible. This aids the pilot in visually acquiring the system. It also makes it possible for the pilot flying back-up to plan his back-up pattern.

b. Minimum altitude for recovery is 400' absolute altitude at contact. If the aircraft is not inbound 20 seconds or less out when the system reaches 1,000', it is obvious a recovery cannot be made.

c. Using only the two inboard throttles in the recovery pattern is recommended in order to minimize yaw (from possible assymetric power), caused by throttle setting or engine differences. However, some experienced recovery pilots perfer using all four throttles and compensate for uneven power effects with rudder. New recovery pilots will generally do better by using only the inboards until their recovery judgement is highly developed. All pilots, however, should be prepared (especially less than 10 seconds out) to use all four throttles for a pull-off if necessary.

d. The parachute system, as mentioned in Section II "flies" (descends) according to its indicated vertical airspeed. Thus its actual descent rate (TAS) decreases with decreased altitude. The aircraft may be able to "stay with" a system, at a lower altitude, when it would not at a higher altitude.

e. Stresses on the system during recovery are chiefly a function of aircraft true airspeed, winch performance, type of contact and type of system, although there are other factors. One way to help reduce stresses on the system is to plan contact at a lower altitude (lower TAS). If maximum altitude (15,000' MSL) must be used, the only way to minimise stress caused by the TAS is to fly the bottom side of the allowable indicated airspeed envelope(120 knots). The aircraft should be flown more carefully, i.e., the pilot should be more reluctant to accept a chance for a mediocre contact, i.e., pull off if possible, when flying near the upper limits of both the altitude and the airspeed envelope at the same time. The best assurance of a successful recovery at any altitude, or any airspeed, is a good contact. This is especially important when nearing the airspeed and altitude limits.

f. Inboard engine power of 5,000 pounds torque or below is recommended during rigging, drop and reel-in. The purpose of this procedure is to minimize the possibility of turbulent airflow around and behind the fuselage. However, if more inboard power is needed to maintain level flight, there should be no reluctance to use it.

g. When the recovery crew is working, they are not secure and can be likened to eggs in a tin box. The pilot must at all times show his awareness of this situation by his handling of the aircraft. The crew and equipment must be secured any time other than smooth, stable essentially one "G" flight might be expected.

V THE HIGH SPEED (EDF) RUN

1. General:

a. The first four sections have contained information basic to the actual aerial recovery. The remaining sections present techniques used prior to the recovery pattern, and supplemental procedures appropriate for training in support of the overall unit mission.

b. The high speed run is used when the aircraft is not initially within visual range of the system. Using the Electronic Direction Finding (EDF) Equipment as the primary source of bearing information, it is designed to put the aircraft within visual acquisition range in minimum time, and in a position to work the system at the highest possible altitude.

c. The manner in which a run is made depends upon whether or not the system position, relative to the aircraft position, is known. However, all runs begin with the recovery aircraft at an "On Station Position" (O.S.P) at a given altitude, with a predicted parachute deployment time and altitude. For high speed run training a drop aircraft drops a system at the prescribed time and altitude. Mounted on the system is an electronic beacon which the EDF operator can track to provide the pilot with bearings to the system. In "Homing" to the system, pilot procedures are much the same as for ADF Homing.

d. All alternate equipment that will aid system interception should be used to back up the EDF equipment. The UHF/DF position of the UHF command radio may be selected and turned to the beacon frequency, if appropriate. The aircraft radar may also be able to track the system, but cannot be counted upon, as radar acquisition usually occurs at less than 25 miles range. Dead reckoning procedures, of course, useful only if the position of the system is known.

e. Regardless of the distance to be run, the pilot needs to know the parachute deployment (drop) altitude, time, and expected system descent rate (time-to-fall data). For training, the recovery aircraft OSP altitude is usually between FL200 and FL250, and the drop aircraft at least as high. At parachute deployment time the pilot should start his clock for elapsed time, turn to the system bearing, and, unless he knows his aircraft is close (within 20 miles) to the system and at least 10,000 feet below it, begin descent to achieve a high airspeed. The descent is planned so that the running recovery aircraft will stay a minimum of 4,000 feet below the system altitude, estimated from elapsed time and the time-to-fall data, until approaching sea level makes this separation impossible.

f. Highest average true airspeed will normally be achieved using maximum continuous power. However, C-130 handbook 2.5G structural indicated airspeed limits must not be exceeded. When turbulence may be expected, as in passage through cumuliform clouds or known areas of CAT, the use of the 3.0G airspeed limit is recommended. If rapid descent is required, it will be necessary to reduce power to remain within either limitation.

2. Distance Run - System Position Unknown:

a. When the distance from the aircraft to the system is unknown and could be at extreme range, the pilot must try to cover as much distance as possible within the available time-to-fall, while remaining below the system. With distance (thus average true airspeed) the prime consideration, interception of the system at the highest working altitude by necessity must be given lesser consideration. At maximum continuous power, the aircraft cannot descent at a normal system descent rate and remain within its airspeed limits. Therefore, descent should begin early enough to keep the aircraft well below the system allowing a lower rate of aircraft descent. This will avoid a forced power reduction later to keep the aircraft below the system. The run should be planned so that the system can be thought of as overtaking (vertically) the aircraft but never quite catching it. Potential run performance also is lost any time the aircraft must level off, which reduces the run speed to maximum cruise airspeed. Descending too rapidly, too soon, would force the aircraft to level off (and slow down) for sea level with the system far above. A properly flown high speed run for distance is a continuous high speed descent resulting in the aircraft approaching sea level 2 to 5 minutes ahead of estimated system splash, without the necessity for power reduction or level off prior to visual acquisition, station passage, or aircraft altitude 400 feet above sea level, whichever occurs first. Average aircraft descent rate, depending upon the time-to-fall, will generally be between 1000 and 1500 FPM for initial aircraft altitudes above FL200, resulting in airspeeds approximating the 3.0G limit for most of the run.

3. Short Run - System Position Known:

If the system position is known to be a relatively short distance away (say,less than 50 miles with an ample spread between initial system and aircraft altitude), average run speed decreases in importance. The pilot may choose to sacrifice some airspeed in order to intercept at a higher altitude to make visual acquisition easier, to permit a higher altitude inspection pass, or because of low altitude weather. Regardless of the profile chosen, the aircraft should arrive sufficiently below the system to allow leveling off, slowing down, and deployment of the rig. Normally, the established planning minimum of 4,000 feet vertical separation is sufficient. Since 15,000 feet MSL is the highest recovery altitude normally permitted, aircraft altitude at interception must be carefully palnned to allow time for slow up and rig, yet not waste working altitude.

VI The Weather Box - Station Passage and Visual Acquisition Procedures

1. Prior to visual acquisition, vertical separation from the system must be maintained, normally 4000 feet or more below the published TIME-TO-FALL DATA raindrop. An additional safety factor can be obtained by flying a 5 or 10 degree offset heading when in the known area of the system and just prior to station passage. This can be determined from experience in working with the EDF Operator and from an ETA provided by the navigator based on the predicted grid reference as determined from bearings of the other force aircraft.

2. Upon electronic station passage, slow the aircraft to a stabilized airspeed (120 - 131 KIAS recommended) at which the weather box will be flown. This slow down and entry into the weather box may be done in any number of ways. Two of which are mentioned here:

3. Upon station passage begin timing of the weather box, reduce power to zero torque, maintaining a descent higher than that of the system, and continue outbound for 15 seconds. Turn left, 90 degrees and hold this heading 20 to 30 seconds. Turn left, 90 degrees and continue this left hand pattern. Adjustments in the pattern may be made if the DF bearing to the system is significantly off the wing tip position at the 30 second point of a one-minute leg of the weather box.

4. A second method is to execute a 20-30 second teardrop pattern and return to the system slowing to a stabilized airspeed (120-131 KIAS recommended). Upon second station passage begin timing of the weather box maintaining a constant IAS and a rate of descent higher than that of the system. Normally a one-minute left hand pattern is flown. Adjustments may be made as described above.

5. Once established in the weather box, deployment of the recovery rig may be accomplished during the descent phase or after visual flight conditions are achieved. Normally, deployment of the rig in the descending pattern is most desirable since early deployment of the rig will release the recovery crew [illegible] to ~~attempt~~ visual acquisition of the system once it has descended clear of the clouds. Once visual flight conditions have been achieved, and the loop deployed, it is recommended that a level box pattern be maintained about 1500 feet below bases of the cloud deck.

6. When a recovery is to be made between cloud layers, a clear area of at least 5000 feet is desirable. It is unlikely that a successful recovery can be made from a one-minute box pattern with less than 2500 feet between cloud decks.

VII The Look-See Pass

Once visual sighting of the parachute occurs, two types of inspection passes may be made, namely with the aircraft rigged or unrigged for aerial recovery. The unrigged look-see is normally performed at or above 25,000 feet MSL since the aircraft should not be flown unpressurized above this altitude. The rigged look-see can then be made below 25,000 feet MSL.

A. Unrigged look-see - When making a high altitude, unrigged, look-see, consideration must be given to the excessive rate of descent of the system (greater than 2500 fpm) and the reduced turning radius of the aircraft. If a circling pattern is flown then the aircraft should be kept some six miles from the system. When the parachute begins to approach the horizon, a turn toward the descending system should be initiated. It is important to remember that at high altitudes the aircraft and parachute are at about the same altitude when the system appears to be one or two system lengths above the distant horizon. The look-see pass should cause the parachute to pass just to the left of the wingtip, level or just slightly above the aircraft. This pass will also permit evaluation of the actual parachute descent rate as well as the condition of the parachute and suspended weight. The operations plan contains specific information regarding evaluation of the parachute system.

1. High Speed Descent - After completion of the unrigged look-see pass, the quickest method of descending to a "working" altitude or backup position is by means of a high speed descent. This is accomplished by raising the flaps to zero degrees, retarding the throttles to flight idle, and descending at or near maximum allowable KIAS until 2000 feet below the desired level off altitude. It is of course important to maintain visual contact with the parachute and other aircraft at all times if possible. A penetration tear drop pattern may be accomplished, expecially if instrument conditions are present. Consideration must be given to insure that descent is made away from other aircraft and that return to the system made so as to arrive outside a normal weather box pattern or below other aircraft in the recovery area. Keeping other aircraft commanders advised of your intentions and actions is imperative for obvious safety reasons.

2. Low Speed Descent - An alternate method that may be used after completion of an unrigged high altitude looksee is a low speed descent. This is performed by lowering 100% flaps, lowering the landing gear, opening the air deflectors and descending so as not to exceed 145 KIAS. With this type descent it is only necessary to descend to the desired level off altitude and not below. The landing gear should be raised just prior to level off and the flaps raised to 50%. The advantages of a low speed descent are:

a. Allows aircraft to remain close to the parachute system.

b. Usually easier to maneuver into back-up position behind primary aircraft.

c. Places less stress on aircraft in turbulent weather conditions

d. Allows aft cargo door ramp to be opened if desired while still descending.

The disadvantages of a low speed descent are:

a. At higher altitudes the descent rate of the parachute system and aircraft are approximately equal.

b. Takes longer to arrive at desired altitude and deploy aerial recovery rig than when using high speed descent.

3. Possibility of forgetting to raise landing gear exists.

B. RIGGED LOOKSEE - If the aircraft making the looksee is supposed to act as back-up for the primary aircraft, the most desirable pattern that can be flown is the rigged looksee. When using this procedure, the aircraft should be slowed and the aerial recovery rig deployed prior to the looksee pass. Slowing and rigging is normally done at 18,000 to 20,000 feet MSL, weather conditions permitting. Obviously, this procedure can only be used when the aircraft is positioned close to the descending parachute system with a great deal of vertical separation. Once the aircraft is readied for aerial recovery, the pilot should continue to circle the system in a counterclockwise direction while waiting for the parachute to arrive at his altitude. Many variations of this procedure are of course possible. For example, the aircraft could be rigged at 16,000 ft MSL and then a climb initiated in the rigged condition so as to meet the parachute and perform the looksee at 18,000 or 20,000 ft MSL. Some of the advantages of the rigged looksee are:

1. Allows more time to rig aircraft for aerial recovery in the event of difficulties.

2. Allows the aircraft to stay close to the parachute at all times.

3. Usually very easy to maneuver into a proper back-up position since pilot is not distracted by procedures and/or difficulties of rigging aircraft. One word of caution on using such a procedure, the pilot should emphasise to all crew members the proper utilization of

PROBABILITIES OF SUCCESS

1. The recovery gear envelop contains a total of approximately 268 sq. feet of area inboard of each pole when extended. This represents a distance of 20.5 feet between pole tips and a vertical distance of 18 feet from the outer skin of the ramp door to the pole tip. The recovery envelop is divided into four zones between the poles and four additional zones below and outside the pole areas as shown on figure 10.

2. Parachute reference point for computing zonal contacts relative to the recovery envelop is the center of the parachute skirt. Even through successful recoveries have been made with contacts outside the pole areas, this is not desirable. Zones 1, 2 and 3 represent the areas of highest probable success. Zones 5 and 7 are the next most probable areas while 6, 4 and 8 are the least probable and least desirable areas of contact. An example of actual statistical data compiled from April 1964 to Feb 1966 is shown below for recovery qualified pilots as a group:

	TOTAL SYSTEMS WORKED	% SUCCESSFUL
1	954	100
2	319	100
3	236	100
5	377	99.5
7	14	92.9
6	102	89.2
4	181	81.2
8	50	74.0
TOTALS	2233	97.2

Individual recovery qualified pilot results for each month are furnished showing the number of systems worked and the success or failure of each zonal contact.

oxygen. All crew members should monitor each other closely since hypoxia could affect a crew member quickly while working unpressurized at high altitude. Regardless of the type "looksee" that is being performed, the pilot should be "rolled out inbound" before a parachute reaches the visible horizon. It is much more desirable to have to climb slightly while inbound then have to dive the aircraft in order to pass level or slightly below the parachute on the inspection pass. Remember, a low IAS at high altitudes still gives a high TAS with resultant high closure rate on the parachute. Keep the airspeed between 120-130 KIAS when possible. You have gone to a great deal of trouble in preparation for the inspection pass so make the looksee a good one. One last, but very important tip, do not circle too close to the system while waiting for it to approach the horizon and then find you are in a constant turn and unable to roll out inbound to the system. Remember that 30 seconds out at 28,000 feet MSL and 125 KIAS requires over 1/2 mile greater lateral separation from the parachute then 30 seconds out at 10,000 feet MSL and 125 KIAS.

Waiver of Looksee - In the event weather or other circumstances do not allow sufficient time for accomplishment of a normal looksee, the Aircraft Commander has the authority to perform a cursory looksee while "inbound hot" on an aerial recovery pass. This authority will be used with discretion.

FIGURES

1. Calculated aircraft maneuverability discussion, with respect to a descending system, has been minimized in the text simply because no two pilots, aircraft, atmospheric conditions, or recovery situations combine in the same fashion twice.

2. The tabulated data in figure 11 is from an E-6B computer, the AFM 51-37 turn performance chart and then combined graphically.

3. The charts, in themselves, prove very little than an experienced Recovery Pilot does not already know or that a student does not intuitively feel. They are included to validate recommended techniques, pictorially present varied patterns and to allow visual comparison of changing TAS effects.

a. Figure One: Using data at a constant 7500 ft., the effect of only bank angle change is shown to scale with elapsed time, system altitude loss, and maximum distance from system listed.

b. Figure Two: The effect of 5000 ft intervals between four tear drop patterns incorporating both aircraft and system change in TAS.

c. Figure Three:

(1) Aircraft maneuvering varies widely between pilots when a last minute, low altitude pattern is flown. The numbers on this chart probably differ more ~~greater~~ (plus and minus) than do the other charts from actual experience.

(2) The distance outbound, the wings level time inbound, the total elapsed time and system altitude loss before chute contact at 500 ft is the basic information.

(3) Two complete 30 degree and 45 degree bank, 20 second tear drop patterns are shown. For example, the 30 degree bank pattern requires beginning at 3200 feet with wing-tip position at 2100 feet in order to contact the system at 500 feet.

(4) Often there is a tendency to remain too far away from a system when it is at a low altitude. Therefore, a 25 second nominal distance at 7500 feet, with turn-in bank angles and resultant inbound times at sea level is depicted for the sake of comparison.

d. Figure Four: The resulting reduced inbound time and additional system altitude loss is shown when angle of bank is reduced to 25 degrees at the system wing-tip position and then further reduced to 20 degrees during the last 90 degrees of turn.

e. Figure Five: At 15 degrees higher than standard atmospheric temperature, a 25 second outbound leg will put you on a ½ standard rate turning circle when the system is on the wing-tip and will keep you 25 seconds from the system. While you will not be able to fly an accurate 4 minute turn circle around the system for any great length of time, the chart does demonstrate how a nominal 25 second circle closes in with altitude loss. Angles of bank, elapsed time and altitude, and distance are shown from 15,000 feet to Sea level.

f. Figure Six:

(1) Weather Box patterns are probably the most difficult to fly accurately due to system high ballistic drift, aircraft drift (which may ~~will~~ be different) and imposed box entrance. None of these variables can be adequately covered here and the recommended 1 minute-leg pattern with wing-tip/30 second adjustment will minimize these problems.

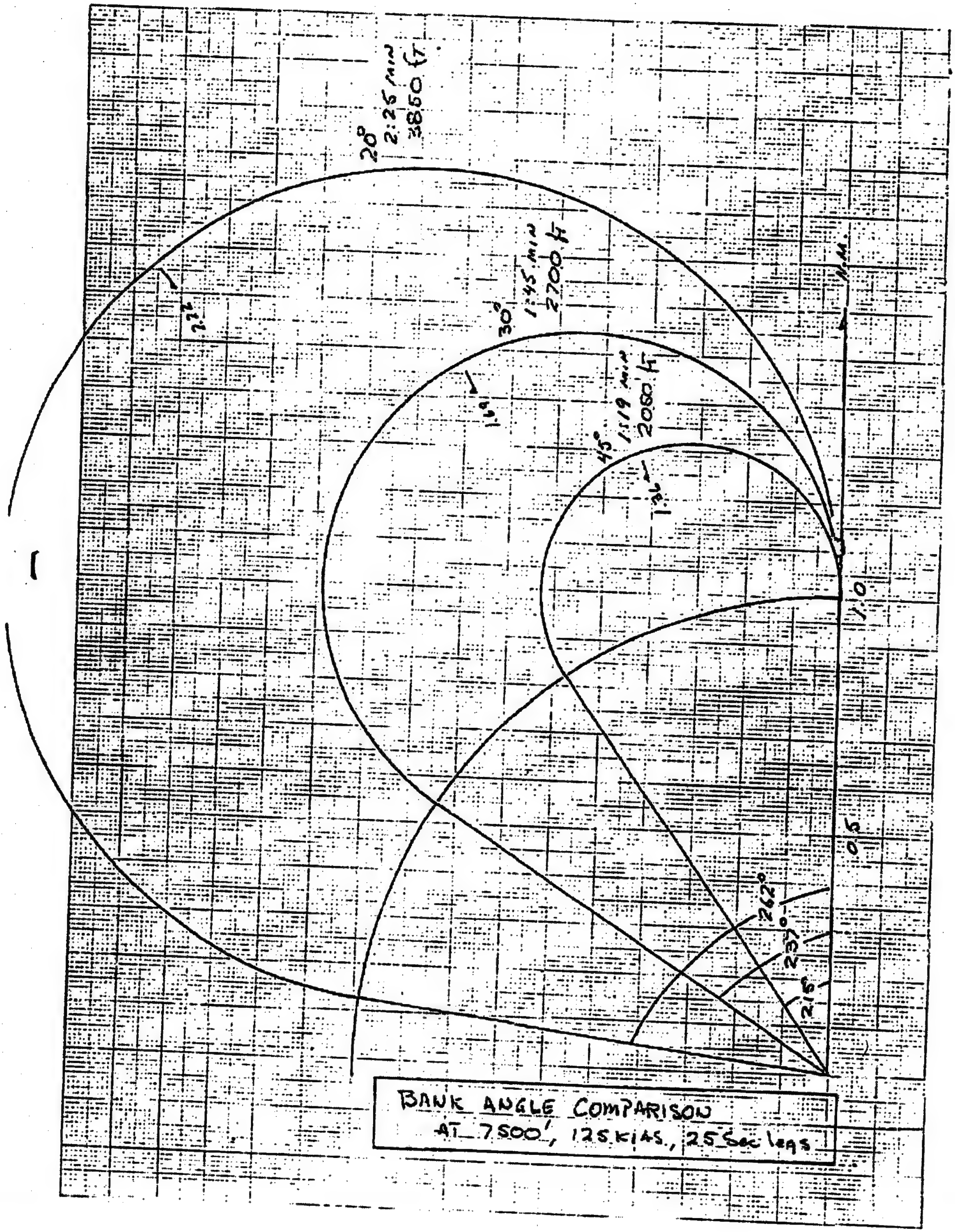
(2) The pattern in figure six is no wind (system or aircraft), 125 KIAS, 30 degree bank and at a constant 7500 feet. The basic 1 minute box is tangential to the ½ standard rate nominal circle at the wing-tip points and only the box width and altitude loss will vary. Note that either a 30 second outbound with a 90 degree left turn or a 25 second outbound with a system wing-tip rollout will establish the aircraft at the recommended distance.

(3) A full tear-drop, wing-tip, and maximum distance away patterns at 7500 feet are also included.

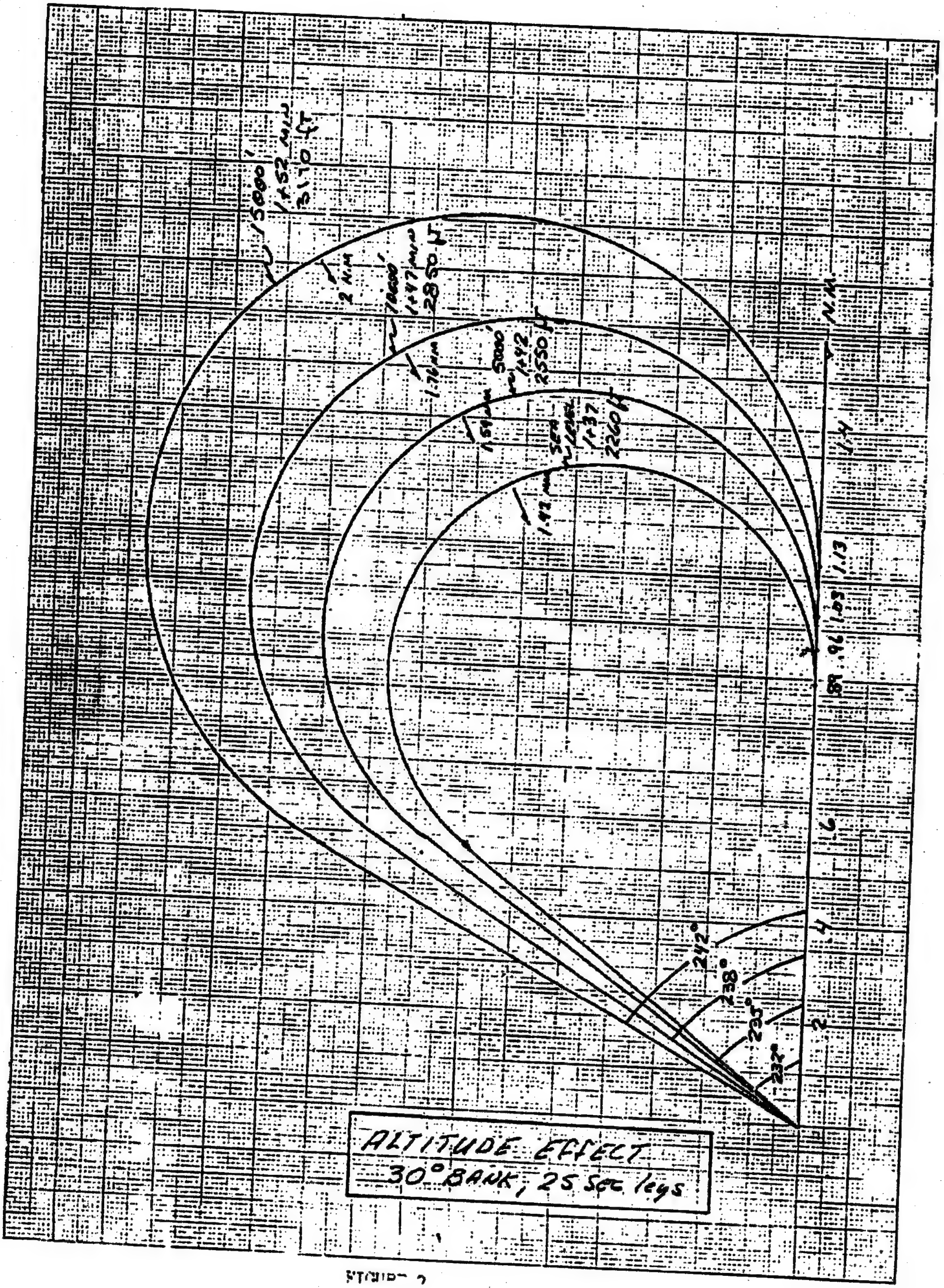
(4) If the EDF bearing was steady enough to use as an ADF, the system bearing would be 35 degrees aft of the wing tip 30 seconds after passage and 35 degrees ahead of the wing tip after the 90 degrees turn and the beginning of the next leg. But using the 35 degrees check point under significant drift conditions would probably do more harm than good due to system ballistic drift and aircraft drift differences.

g. Figures Seven and Eight: These charts show vertical and horizontal views of continuous tear-drop patterns from 1500 feet with TAS as the only variable.

h. Figure Nine: This chart shows resultant wings level inbound legs if the system is maintained at 1.75 NM.

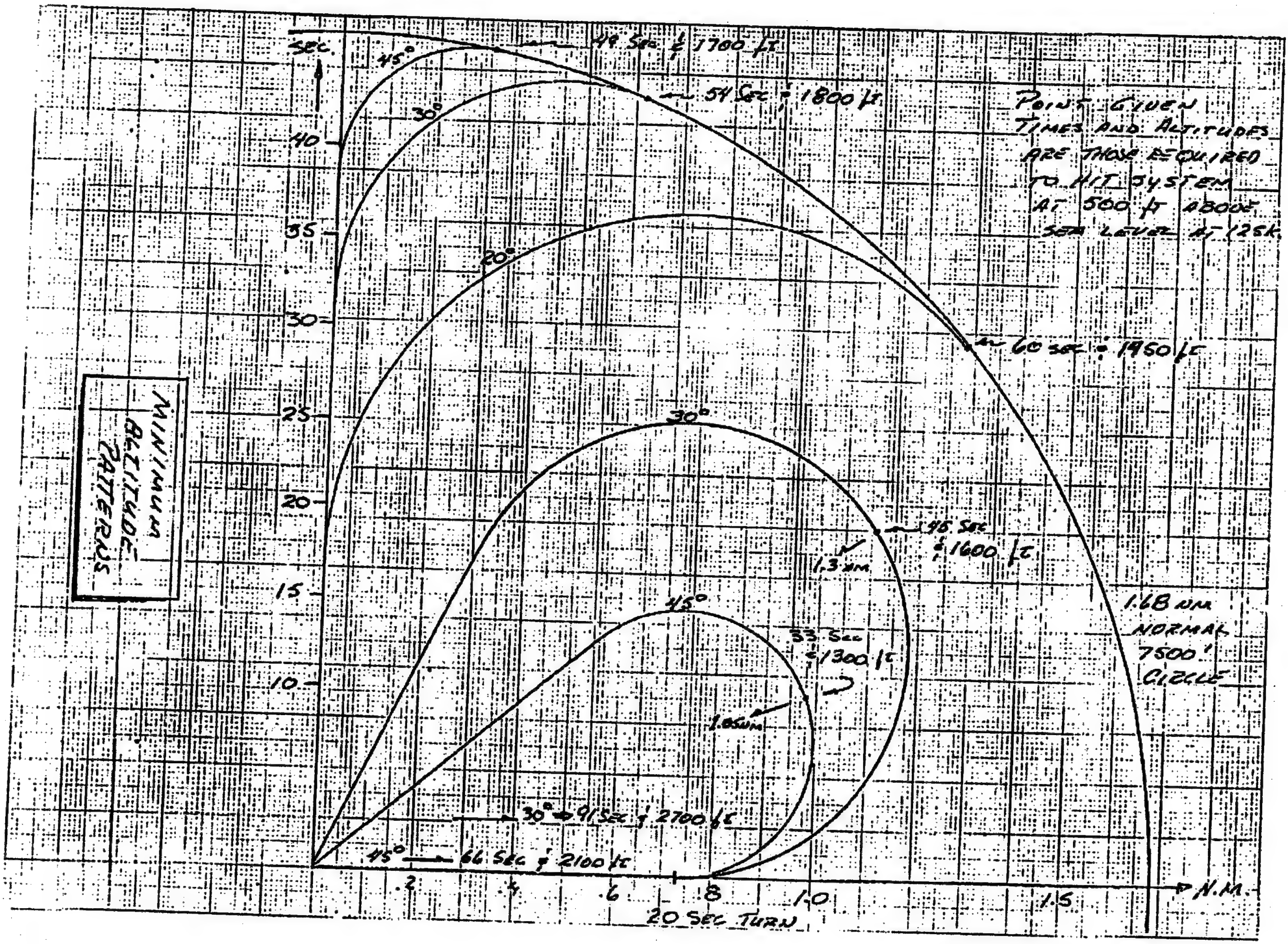


BANK ANGLE COMPARISON
AT 7500', 125 KIAS., 25 Sec legs



ALTITUDE EFFECT
30° BANK, 25 Sec. legs

FIGURE 2



MINIMUM ALTITUDE PATTERNS

POINT GIVEN TIMES AND ALTITUDES ARE THOSE REQUIRED TO HIT SYSTEM AT 500 ft ABOVE SEA LEVEL AT 125K

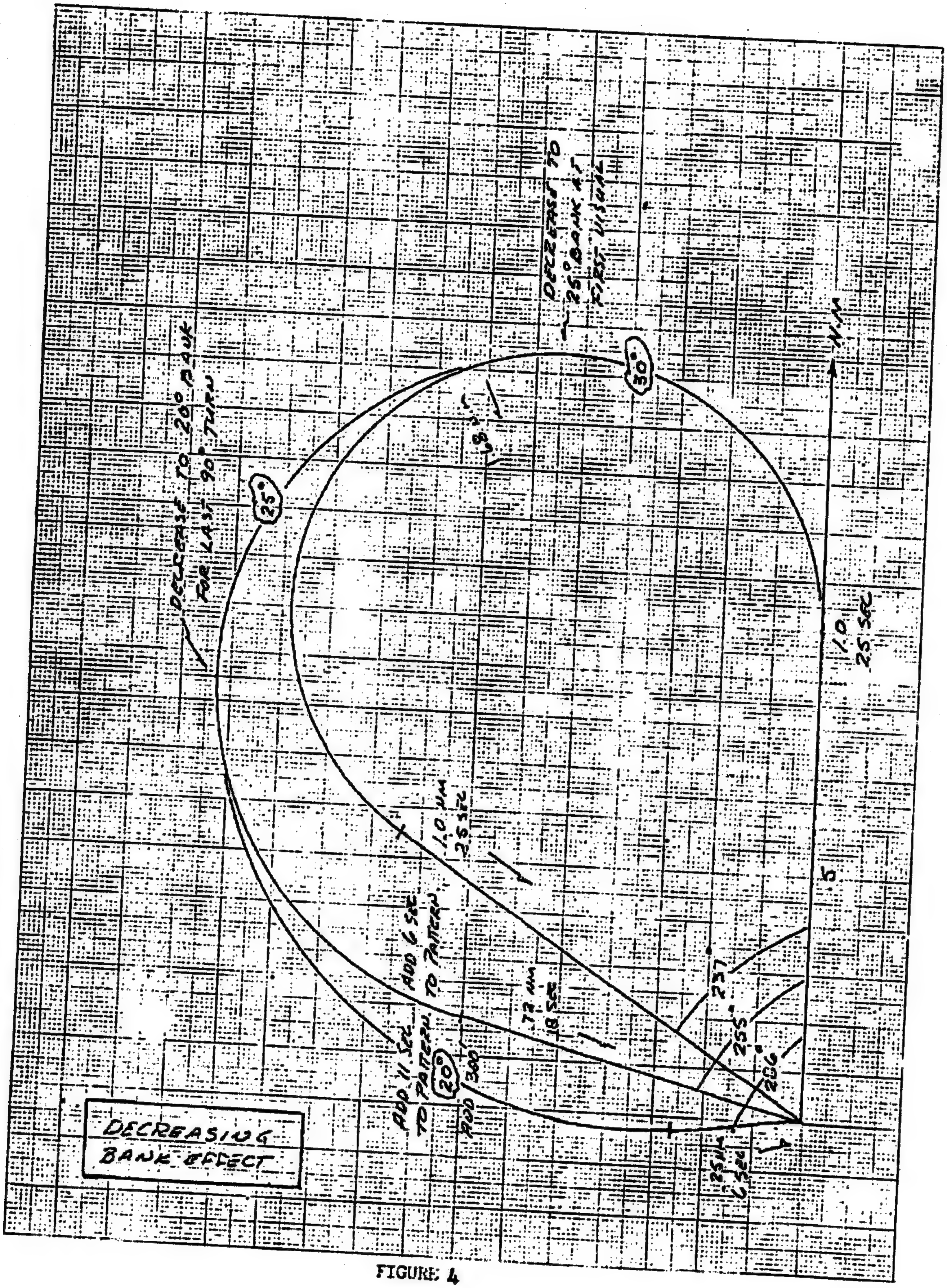
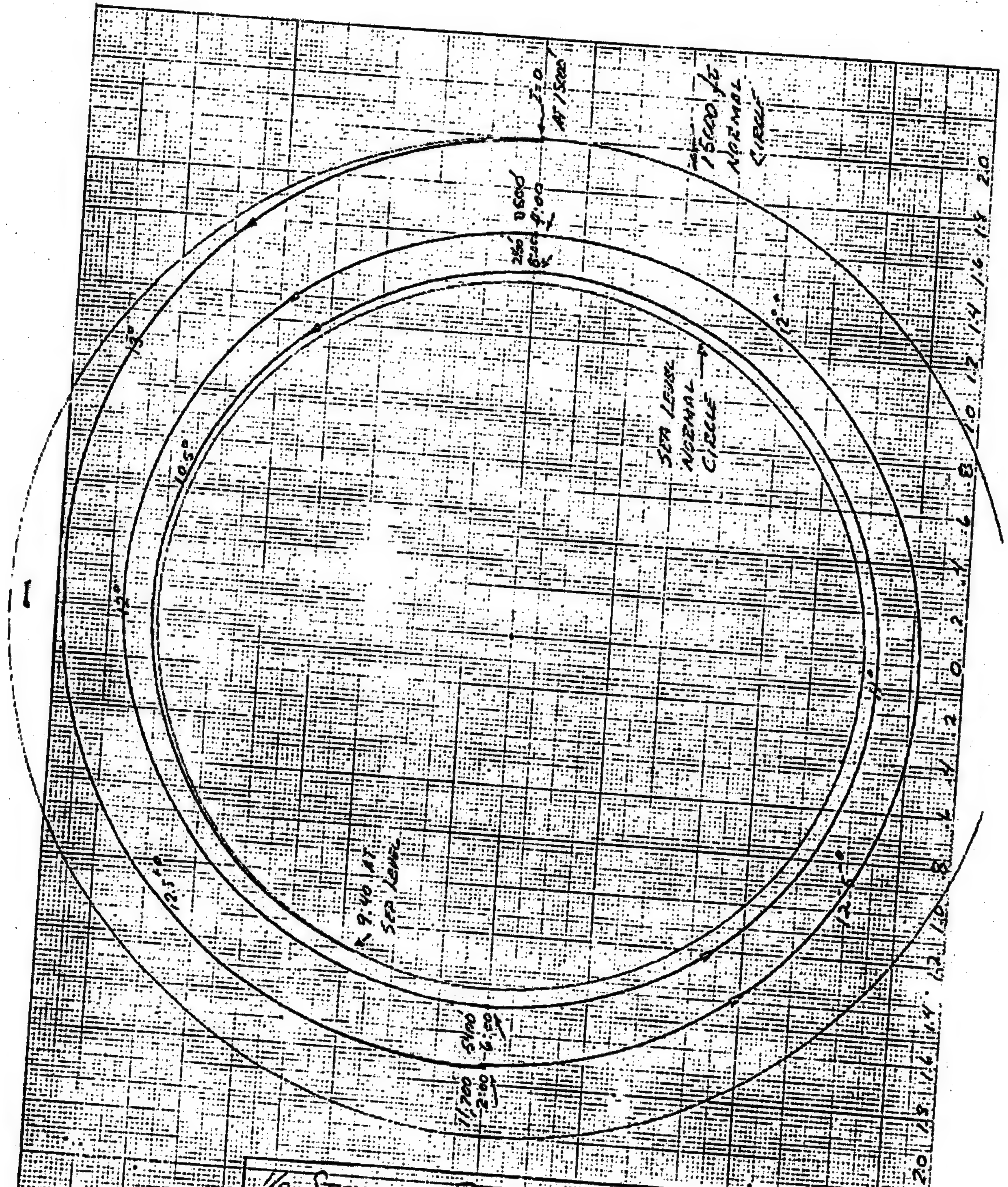

DECREASING BANK EFFECT
DECREASE TO 20° BANK FOR LAST 90° TURN
25°
30°
DECREASE TO 25° BANK AT FIRST VISUAL
N.M
1.0
25 SEC
5
.8 NM
1.0 NM
25 SEC
ADD 6 SEC TO PATTERN
.72 NM
18 SEC
ADD 11 SEC TO PATTERN
20°
ADD 300'
257
255
206
.25 NM
6 SEC

FIGURE 4



1/2 STANDARD RATE (1½ °/s) – 4 MINUTE
CONTINUOUS CIRCLE
FROM NORMAL 15000' TO NORMAL SEA LEVEL CIRCLES

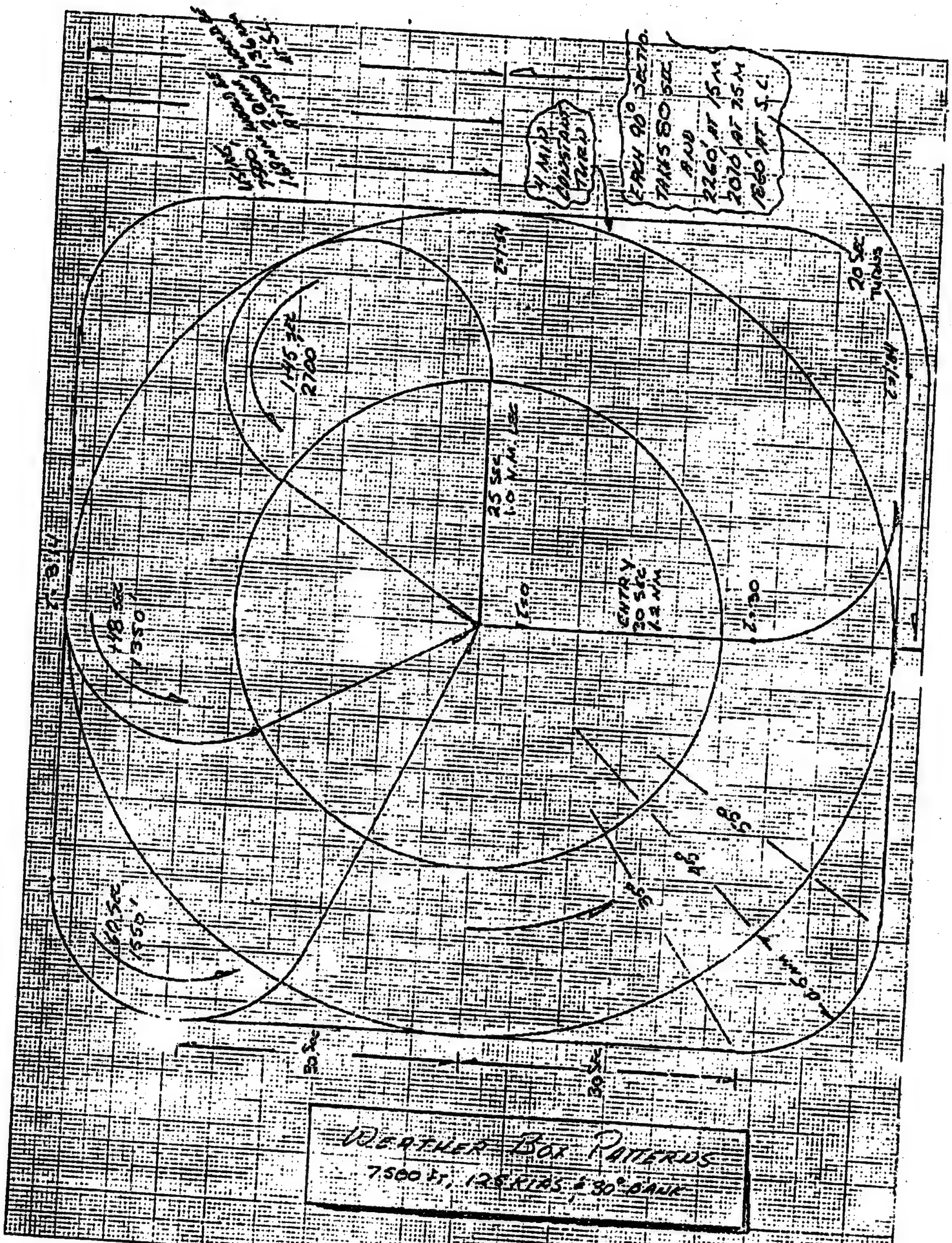
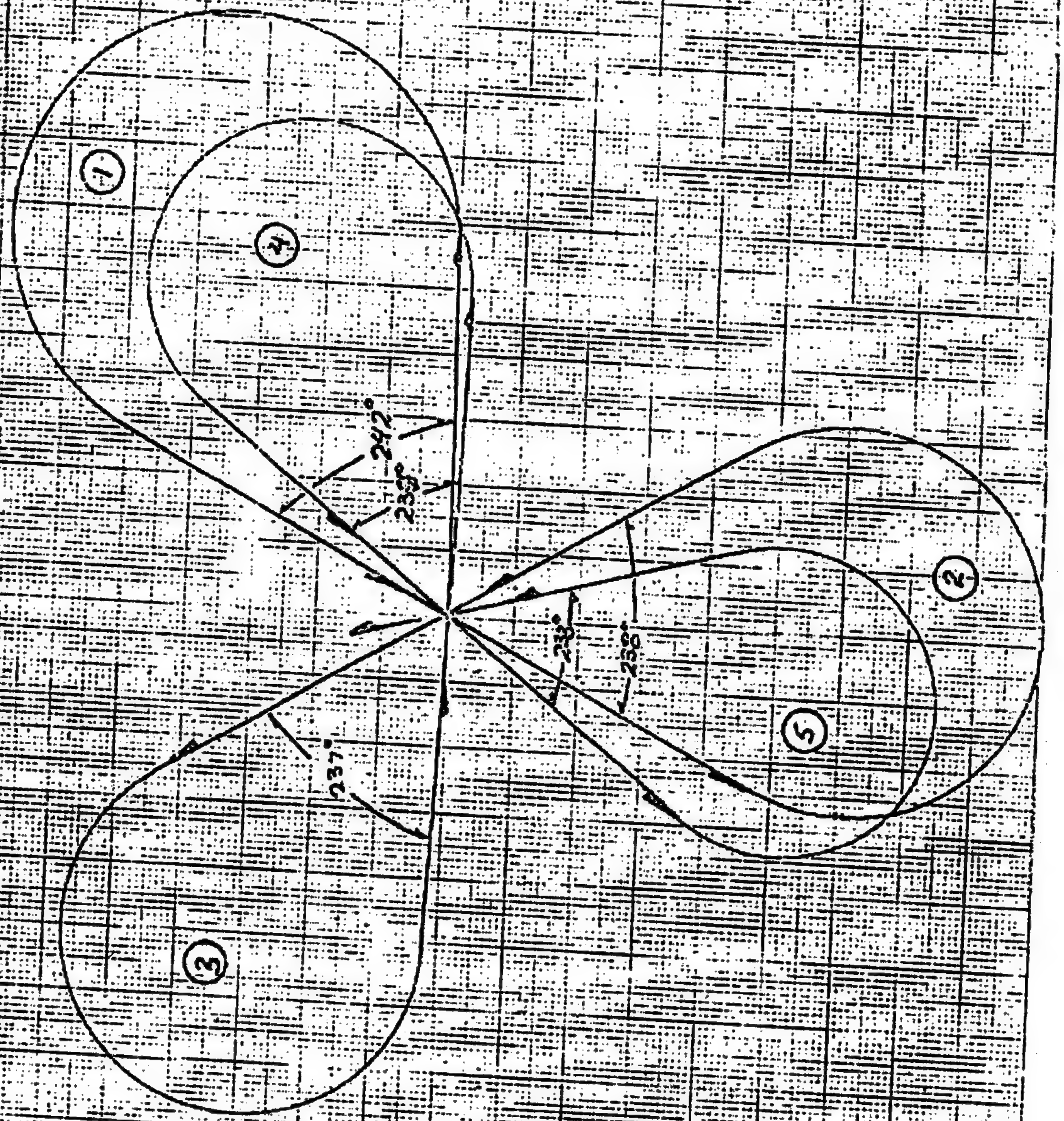
WEATHER BOX PATTERNS
7,500 FT, 125 KIAS, 30° BANK
EACH 90° SECTION TAKES 80 SEC AND 2260' AT 15M, 2070' AT 7.5M, 1860' AT S.L.
4 MIN CONSTANT TURN
25 SEC 1.0 NM
ENTRY 30 SEC 1.2 NM
150
145 SEC 2700
148 SEC 1350'
62 SEC 1550'
20 SEC TURNS
30 SEC
30 SEC

FIGURE 6



CONTINUOUS PATTERNS
15000 FT & BELOW
125 KIAS, 30° BANK
PART ONE

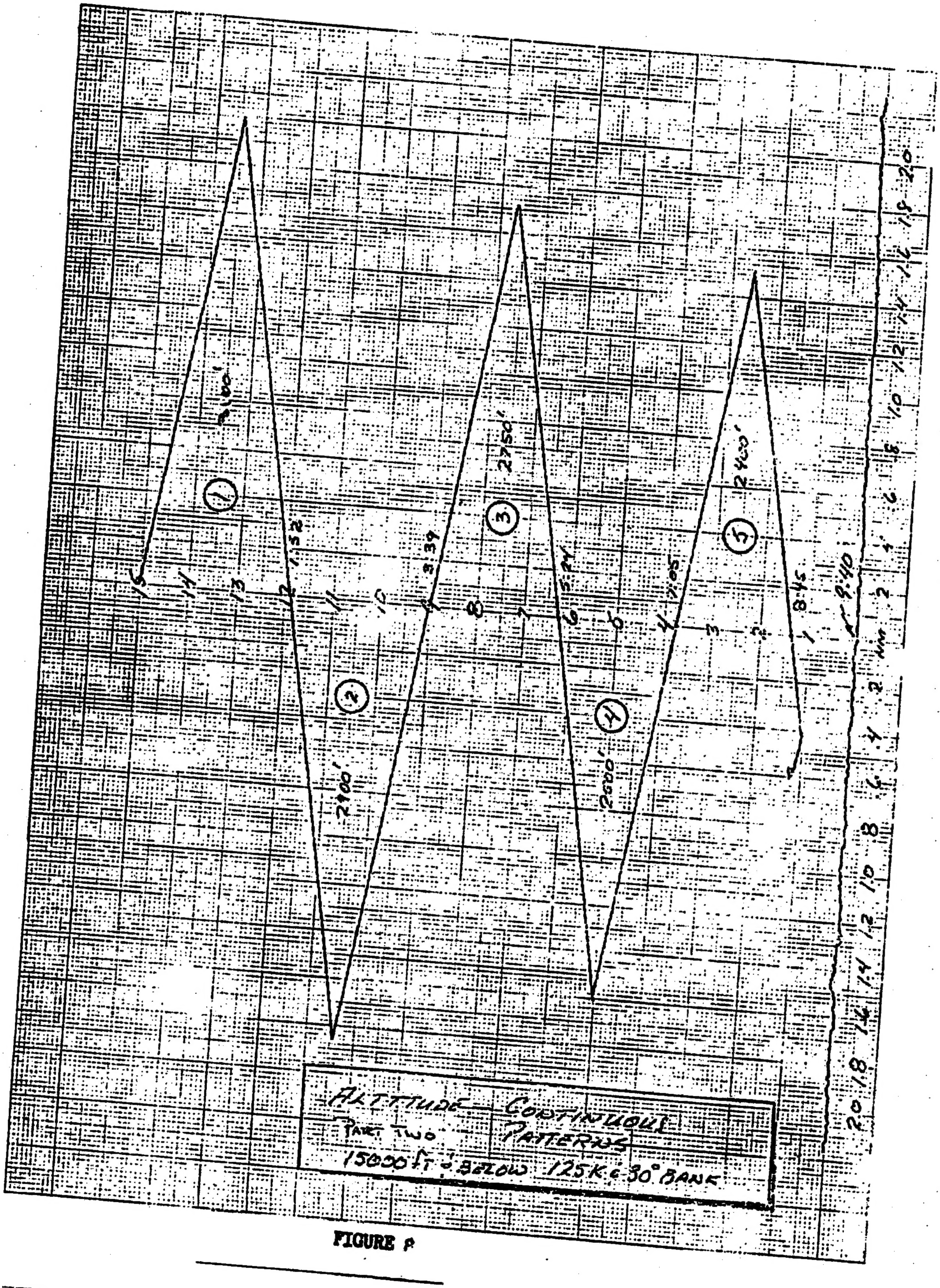
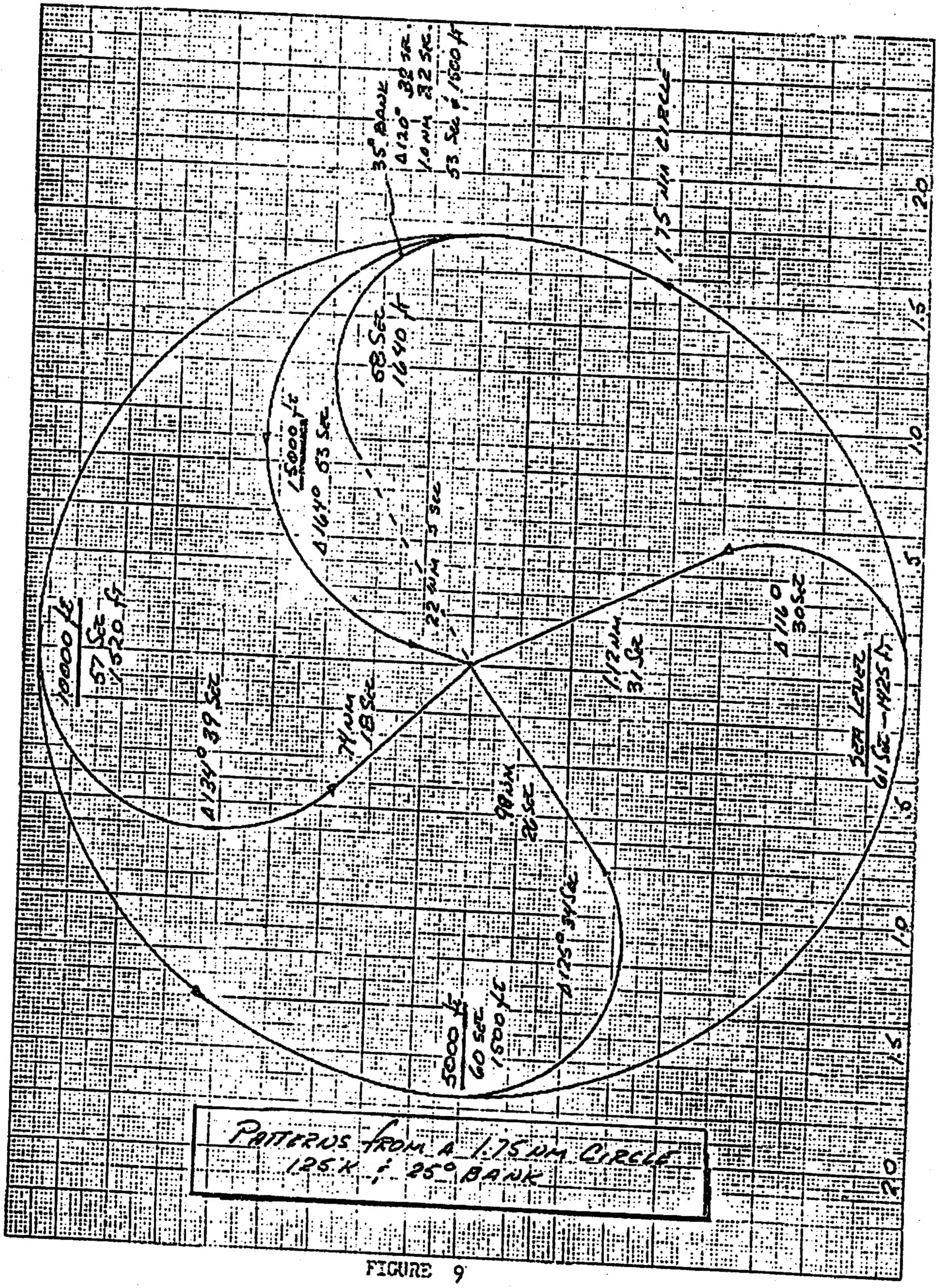

ALTITUDE — CONTINUOUS
PART TWO PATTERNS
15000 FT & BELOW 125K & 30° BANK
①
②
③
④
⑤
3100'
2700'
2750'
2000'
2400'
1:52
3:39
5:24
7:05
8:45
9:40
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
NM
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0

FIGURE 8

K•E



PATTERNS FROM A 1.75 NM CIRCLE
125 K ; 25° BANK

FIGURE 9

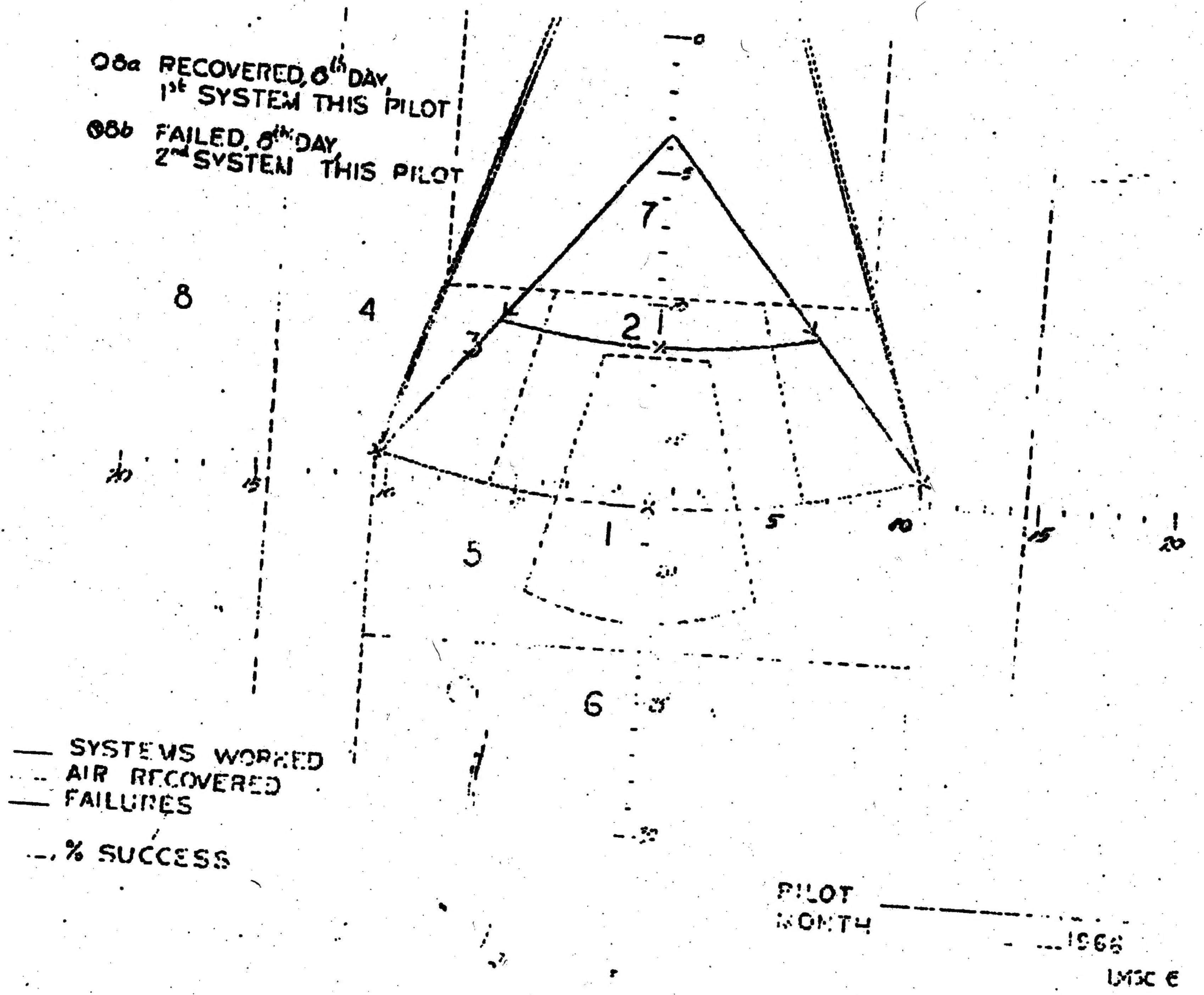

8a RECOVERED, 8th DAY, 1st SYSTEM THIS PILOT
8b FAILED, 8th DAY, 2nd SYSTEM THIS PILOT
0
5
7
8
4
2
3
1
5
6
10
15
20
5
10
15
20
— SYSTEMS WORKED
- - AIR RECOVERED
— FAILURES
- . % SUCCESS
PILOT
MONTH
1966
LMSC E

FIGURE 10

RATE OF TURN CHART

30°Bank 125 KIAS STD+15°C	Rate of Turn (o/Sec)	Rate of Turn (o/Min)	(Radius of Turn (ft)	(Radius of Turn (N.M)	TAS (N.M/Hr)	TAS (N.M/Min)	N.M in 20 Sec	N.M in 25 Sec	N.M in 30 S
15,000	3.9	234	4150	.683	162	2.70	0.94	1.13	1.35
12,500	4.1	246	3700	.625	155.5	2.59	0.86	1.08	1.29
10,000	4.2	252	3500	.575	149	2.48	0.83	1.03	1.24
7,500	4.4	264	3300	.542	143.5	2.39	.080	0.99	1.19
5,000	4.55	273	3050	.502	138	2.30	0.77	0.96	1.15
2,500	4.7	282	2850	.47	133	2.22	0.74	0.92	1.11
1,250	4.8	288	2750	.453	131	2.18	0.73	0.91	1.09
SL	4.9	294	2650	.435	128	2.13	0.71	0.89	1.06

VERTICAL SPEED

20,000 ft - 1800
15,000 - 1700
10,000 - 1600
5,000 - 1500
SL - 1400

Using 7,500 ft as average	Angle of Bank	Rate of Turn (o/Sec)	ROT (o/Min)	Radius of Turn (ft)	Radius of Turn (N.M)	N.M in 25 Sec	TAS (N.M/Hr)
120 KIAS	20 30 45	2.85 4.6 7.9	171 276 474	4900 3100 1700	.807 .510 .280	.96	138
130 KIAS	20 30 45	2.65 4.2 7.3	159 252 438	5900 3500 2050	.970 .575 .338	1.04	149
125 KIAS	20 30 45	2.75 4.4 7.5	165 264 450	5350 3300 1900	.880 .542 .312	1.00	144
At 1200 ft KIAS	20 45	3.0 8.4	180 505	4400 1600	.725 .26		

FIGURE 11